United States
Department of
Agriculture

Forest Service

**Pacific Southwest
Forest and Range
Experiment Station**

P.O. Box 245
Berkeley
California 94701

Research Note
PSW-345

September 1980

Large Stock and Fertilizer Improve Growth of Douglas-Fir Planted on Unstable Granitic Soil in Northern California

R. O. Strothmann

Strothmann, R. O.
1980. *Large stock and fertilizer improve growth of Douglas-fir planted on unstable granitic soil in northern California.* Res. Note PSW-345, 7 p., illus. Pacific Southwest Forest and Range Exp. Stn., Forest Serv., U. S. Dep. Agric., Berkeley, Calif.

Douglas-fir seedlings planted on granitic soil on the Klamath National Forest in northwestern California were studied to see if planting large stock or adding fertilizer would significantly improve survival or growth, or both. Use of large stock and fertilizer resulted in significant increases in height growth of seedlings, but not in better survival. Most mortality occurred during the first growing season and was attributed to drought. The study was not intended to assess the reduction in erosion that might result from the plantings. Also, because research was restricted to one locality and one planting season, only limited inferences can be made as to applicability of the results.

Retrieval Terms: Pseudotsuga menziesii (Mirb.) Franco var. *menziesii*, planting, planting stock, seedling size, fertilization, seedling survival, height growth, erosion, granitic soil, Klamath National Forest, California.

Granitic soils in the Western United States pose special problems in forest management because of their inherent instability. Disturbances associated with logging sometimes trigger earth slides and the eroded site may not revegetate readily. To stabilize erodible slopes, various species of plants have been seeded or planted on them.

Planted ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) has shown promise in reducing erosion from road-fill slopes on granitic soils in Idaho.[1] Maximum erosion control was achieved by combining tree planting with straw mulching and installing netting to hold the straw in place—tree planting alone reduced erosion from 32 to 51 percent. Ninety-seven percent of the trees planted survived four growing seasons; fertilization increased growth an average of 95 percent during the year of peak effect.

The movement of soil and debris can threaten young seedlings in several ways. Seedlings can either be undercut by erosion or buried by deposition. Both erosion and deposition were problems when regeneration of Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco var. *menziesii*) by seed spotting was attempted on soils derived from decomposed granite in northwestern California.[2] More than one-third of the seedspots were damaged; losses from depositon exceeded those from erosion by threefold. Erosion and deposition were found on a cutblock with a slope of only 32 percent as well as on a steeper cutblock with a slope averaging 67 percent.

Planted trees also can be affected adversely by erosion and deposition. In attempts to improve tree survival on unstable sites, larger-than-normal planting stock was tried in western Oregon.[3] On a 50 percent south-facing slope that had been clearcut recently, both 2-0 and 3-0 Douglas-fir seedlings were planted. At the end of two growing seasons, survival of the 3-0 stock was significantly greater—51 percent as against 33 percent for the 2-0 stock. Of the trees that lived through the first bud-bursting stage, 23 percent of the 2-0, but only 8 percent of the 3-0 trees were lost by the end of the first growing season because of surface movement. The trees lost were either uprooted or covered by rock particles, soil, litter, or rotten wood. Superior height was credited as being the variable chiefly responsible for the better survival rate of the 3-0 stock.

resulted in significant increases in seedling height growth, but not in better survival. Most mortality occurred during the first growing season and was attributed to drought.

STUDY AREA

The study site was on the Salmon River Ranger District of the Klamath National Forest in northern California, in the southeast portion of the English Peak Batholith. This area is an intrusive igneous pluton covering about 53 square miles (137 km^2). The batholith varies from a gabbro, through diorite and granodiorite, to a quartz monzonite.[4]

The soils consist primarily of residual and transported material derived from coarse crystalline granitic rock. Weathering of the residual igneous soil is characterized by pervasive fabric disintegration, with only partial alteration of the feldspars to clay.[5] Weathering of the transported igneous soils involves extensive decomposition of primary minerals. Shallow, weathered surface soil 3 to 4 feet (0.9 to 1.2 m) in depth is highly susceptible to debris slides on slopes steeper than about 60 percent.

Soil texture ranges from coarse sand to sandy loam.[6] The structure of the surface soil is weak, very fine, and granular; that of the subsoil is massive. The surface infiltration rate is rapid, and surface erosion hazard is rated as severe. The soils have not yet been formally classified, but are similar in many respects to the Chaix, Chawanakee, Shaver, Holland, Musick, and Hotaw soil series. Suitability for sustained timber production is rated as moderate.

Native commercial tree species include Douglas-fir, which predominates on north and east slopes; ponderosa pine, which predominates on south and southwest slopes; sugar pine (*Pinus lambertiana* Dougl.); and white fir (*Abies concolor* [Gord. & Glend.] Lindl. ex. Hildebr.), which grows mainly at the higher elevations. Hardwoods and brush species include tanoak (*Lithocarpus densiflorus* [Hook. & Arn.] Rehd.), chinkapin (*Castanopsis chrysophylla* [Dougl.] A. DC.), California black oak (*Quercus kelloggii* Newb.), interior live oak (*Q. wislizeni*, A. DC.), Pacific madrone (*Arbutus menziesii* Pursh), deerbrush (*Ceanothus integerrimus* H. & A.), blueblossom (*C. thyrsiflorus* Eschsch.), and bigleaf maple (*Acer macrophyllum* Pursh).

The area is characterized by hot, dry summers with daytime temperatures frequently exceeding 100° F (38° C).[7] Winters are usually wet and cool, with temperatures frequently dropping to 0° F (-18° C) on exposed sites at higher elevations. Annual precipitation averages about 46 inches (1168 mm). Only about 15 percent of the total precipitation normally falls between April 1 and September 30.

The cutblock on which the test seedlings were planted had been clearcut in 1967. Slash was broadcast-burned in fall 1968, and the block was planted with Douglas-fir seedlings in spring 1969. Also, in an effort to stabilize the numerous debris flows that had developed in this highly erodible soil, willows (*Salix* sp.) were planted along the edges of these flows. Although a few willows survived in the wetter areas, survival generally was poor.

Elevation of the study site is about 2600 feet (792 m). Slope steepness is mostly between 60 and 70 percent, approaching a maximum of 80 percent. The plots have predominantly northeasterly aspects.

The slide areas on which the study plots were placed ranged in length from about 30 feet (9 m) to more than 200 feet (61 m), and in width from about 10 feet (3 m) to 30 feet (9 m). Plots were installed mainly in the upper portions of the slides, where gullying was less severe. Even here, however, mass downslope movement had, in places, removed up to 3 feet (0.9 m) of soil and parent material. At the time of plot installation, the slide areas were largely devoid of vegetation, although scattered plants of deerbrush, rose (*Rosa* sp.), a few Douglas-fir seedlings, and several other species were present.

METHODS

In spring 1975, I planted 2-0 Douglas-fir that had been grown at the Forest Service's Humboldt Nursery at McKinleyville, California, from seed collected on the Salmon River Ranger District at an elevation of about 3000 feet (914 m).

Four treatments were tested in a factorial experiment, using a randomized block design with 10 replications. The treatments consisted of two seedling size classes—"large" and "regular" —and two fertilizer levels—"fertilized" and "not fertilized." The two stock sizes came from the same seedbed, and represented grading for size by visual observation in this seedlot.

Large stock differed from regular stock in "huskiness" rather than in height. On the basis of a 25-tree sample from each size class, here is how the two size classes differed:

	Size class	
	Regular stock	Large stock
Characteristic:	Mean ± S.D.	
Top height (cm)	36.32 ± 4.77	39.16 ± 7.08
Root length (cm)	34.24 ± 6.18	47.68 ± 9.32
Stem diameter (mm)	6.12 ± 0.67	8.96 ± 1.02
Top dry weight (g)	6.35[1]	15.84[1]
Root dry weight (g)	3.26[1]	12.17[1]
T/R ratio (wt. basis)	1.95[1]	1.30[1]

[1]Individual seedlings were not weighed; only a group mean was obtained.

To fertilize, a 9-gram, slow-release fertilizer tablet was placed in a hole about 3 inches (7.6 cm) upslope from the stem of the planted seedling, at a depth of about 6 inches (15.2 cm). This procedure was in accordance with the recommendations of the tablet manufacturer,[8,9] who cautions against putting it directly into the planting hole where it could come into immediate contact with the seedling roots. One tablet per seedling was used.

Each of the 10 replications (blocks) consisted of 20 trees planted in four rows of five trees each, with each row comprising a specific seedling-size and fertilizer treatment. Treatments were randomized within each block, with rows oriented up- and downslope so that any downslope movement of fertilizer would affect only trees that

had been similarly treated. Spacing between trees was about 3 feet (0.9 m), both between rows and within rows. All 200 trees were planted by one person using a hoedad.

The trees were planted in mid-April when the weather was cool. Temperatures were in the 40's and skies varied from sunny to partly cloudy. Some brief, light snow fell during the first several hours of planting. Soil moisture was ample because snow had just melted from the site the preceding week. On the evening of the day that planting was completed, and continuing into the following day, a light rain fell. Precipitation for the remainder of the first growing season—May through September—was much below normal, totaling only 1.46 inches (37 mm) compared with a normal of 4.39 inches (112 mm).

Seedlings were examined annually for 3 years. In addition to recording survival and measuring height, I classified each seedling for the severity of erosion or deposition affecting it. In this study, I followed these definitions:

- Slight erosion: minor exposure of the upper portion of the root system, with an inch (2.5 cm) or less of soil removed.
- Moderate erosion: gullying of soil to a depth of as much as 3 inches (7.6 cm), or exposure of up to 25 percent of the seedling's root system, or both.
- Severe erosion: exposure of more than 25 percent of the root system, or undercutting sufficient to topple the seedling.
- Slight deposition: soil buildup around the base of a seedling sufficient to be easily noticeable, but with little or no burial of seedling foliage.
- Moderate deposition: soil buildup that covered all, or most of the lowest whorl of foliage, often causing the seedling stem to lean downslope.
- Severe deposition: soil buildup sufficient to bend the seedling to the ground, usually with burial of more than half the foliage.

At the end of the third growing season, foliar and soil samples were taken to assess the nutrient status of the seedlings and the soil. For the foliar samples (taken in October), fully expanded current year's needles from the upper whorl of lateral branches were used. Needle-bearing twigs were promptly brought to the laboratory, rinsed with distilled water, and then oven-dried at about 70° C for 3 days.[10] The needles were then removed from the twigs and ground in a Wiley mill to pass a 30-mesh screen.

Soil samples were taken from directly downslope of the planted seedlings within 3 inches (7.6 cm) of the stem, from a depth zone extending from 6 to 10 inches (15 to 25 cm) below the surface. Because the fertilizer tablets initially had been placed a few inches upslope of the tree at a depth of about 6 inches, this wa[illegible] zone through which the fertilize[illegible] likely would have been diffused being brought to the [illegible] soil samples were [illegible] sieved through a 2-m[illegible]

The methods used [illegible] are summarized in *ta*[illegible]

Table 1—*Methods used in analyzing nutrient status of seedlings and soil after three growing seasons*

Sample	Method of Analysis	Source
Foliar:		
Total N	Colorimetric; sulfuric acid digestion	Mitchell[11]
Total P	Nitric-perchloric acid digestion; ascorbic acid reduction	Johnson and Ulrich;[12] Murphy and Riley[13]
Total cations (Cu, Zn, Mn, K, Fe, Mg, Ca)	Nitric-perchloric acid digestion; atomic absorption analysis	Johnson and Ulrich;[12] Perkin-Elmer Co.[14]
Soil:		
Total N	Colorimetric; sulfuric acid digestion (modified)	Catlado and others[15]
Available N	Anaerobic incubation; microKjeldahl steam distillation	Waring and Bremner[16]
Available P	Dilute acid extraction; ascorbic acid reduction	Bray and Kurtz;[17] Murphy and Riley[13]
Exchangeable Na, K, Ca, Mg	Ammonium acetate extraction; atomic absorption analysis	Chapman;[18] Perkin-Elmer Co.[14]
Cation exchange capacity	Sodium saturation; atomic absorption analysis	Chapman;[18] Perkin-Elmer Co.[14]
Organic matter	Walkley-Black	Allison[19]
pH	Calcium chloride extraction	Peech[20]

RESULTS

Survival

Considering the h[illegible] site, survival during t[illegible] was good for all tre[illegible] between 78 and 88 [illegible] Highest survival o[illegible] fertilized plots (both size classes) and lowest on the unfertilized plots with large stock. Contingency-table analysis[21] of the survival data, which used numbers of live and dead trees rather than percent survival, revealed that neither stock size nor fertilizer treatment significantly (5 percent level) affected survival during any of the 3 years of observation.

Most mortality occurred during the first growing season. For the large stock, both fertilized and unfertilized,

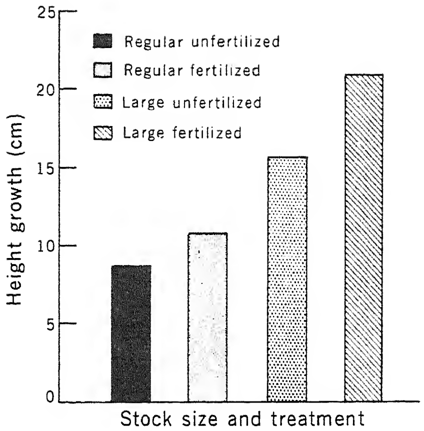

Figure 1—Average 3-year height growth of Douglas-fir seedlings planted on slide areas on a granitic soil, Klamath National Forest, California.

all of it occurred during this first year. For the stock of regular size, a few additional trees died during the second growing season, but none died during the third year. First-year mortality—which comprised 90 percent of all mortality—was attributed to drought.

No cause of mortality could be assigned to two trees that were noted as missing at the start of the second growing season, spring 1976. Both trees were regular stock size, one was fertilized, one unfertilized. A third seedling, however, was positively identified as having been buried by soil movement.

Height Growth

Average height growth of seedlings in the four treatments during the 3-year period was about 25 percent more for the fertilized, regular stock than for the unfertilized, regular stock. The fertilized, large stock grew about 32 percent more than the unfertilized, large stock (*fig. 1*). Even greater height growth differences were evident in comparing the two size classes of stock. The large, unfertilized stock grew 82 percent more than the regular, unfertilized stock; the large, fertilized stock grew 93 percent more than the regular, fertilized stock.

Analysis of variance, using initial seedling height as a covariate, revealed that mean height growth for the 3-year period was significantly influenced (1 percent level) both by tree size class and fertilizer treatment. Interaction of these factors, however, was not significant (5 percent level).

Vigor

Each fall, when survival was checked and heights measured, seedlings were rated also according to vigor (*table 3*). Although somewhat subjective, the classification reveals notable differences among seedlings in the four treatments. The "alive, healthy" category included seedlings having foliage of normal color, length, and density. The "alive, weak" category included seedlings having chlorotic foliage or foliage that was abnormally sparse or short.

At the end of the first growing season, more large seedlings had a healthy appearance than did regular seedlings (*table 3*). Among the regular, unfertilized seedlings, almost twice as many of the survivors were classed as weak (58 percent) as were classed as healthy (30 percent). Among the large seedlings, 66 percent of the unfertilized trees and 82 percent of the fertilized trees were classed as healthy. After 3 years, however, these differences among treatments had largely vanished because many of the formerly weak seedlings had improved in vigor, and 72 percent or more of the originally planted trees in each treatment had a healthy appearance.

Vigor data for each of the 3 years were tested by contingency-table analyses[21] to ascertain whether either stock size class or fertilizer treatment significantly influenced the number of seedlings in the several vigor categories. These analyses revealed that differences attributable to tree size class were highly significant (1 percent level) at the end of the first year, but were not significant (5 percent level) at the end of the second and third years. Differences attributed to fertilizer treatment were significant (5 percent level) at the end of the second year, but were not significant in the first or third years.

Table 3—*Changes in vigor of Douglas-fir seedlings planted on slide areas on a granitic soil on the Klamath National Forest, California*[1]

Year and seedling condition	Size and fertilization			
	Regular		Large	
	Unfertilized	Fertilized	Unfertilized	Fertilized
	Seedlings (*percent*)			
1975:				
Alive, healthy	15 (30)	23 (46)	33 (66)	41 (82)
Alive, weak	29 (58)	23 (46)	6 (12)	3 (6)
Dead or missing	6 (12)	4 (8)	11 (22)	6 (12)
1976:				
Alive, healthy	36 (72)	41 (82)	34 (68)	43 (86)
Alive, weak	7 (14)	3 (6)	5 (10)	1 (2)
Dead or missing	7 (14)	6 (12)	11 (22)	6 (12)
1977:				
Alive, healthy	36 (72)	41 (82)	36 (72)	43 (86)
Alive, weak	7 (14)	3 (6)	3 (6)	1 (2)
Dead or missing	7 (14)	6 (12)	11 (22)	6 (12)

[1]Contingency-table analysis showed that seedling size class significantly influenced (5 percent level) the proportions of seedlings in the several vigor classes only for the first year. Differences attributed to fertilizer treatment were significant only for the second year.

Soil Displacement

At the time of each annual measurement, I noted for each seedling whether soil was being eroded from its root system or deposited against its stem, and I classified the soil displacement as slight, moderate, or severe. I found undercutting to be of minor importance compared with deposition. Only one seedling was undercut, and the erosion in this instance was severe enough to topple it. Enough of the root system was still covered by soil, however, and the tree continued to live.

By contrast, 153 of the 200 trees in the study experienced varying degrees of deposition. Deposition was considered to be only slight for 112 seedlings (73 percent), moderate for 34 seedlings (22 percent), and severe for 7 seedlings (5 percent).

As mentioned earlier, one seedling was killed by soil burial. Only about 1 inch (2.54 cm) of the seedling's terminal shoot remained exposed at the end of the third growing season. Several other seedlings had more than 80 percent of their foliage buried, and I expect that they will be totally buried in a few more years.

I observed almost no differences among treatments as to the number of seedlings adversely affected by soil movement: the number affected ranged from 37 to 39 of the 50 seedlings planted in each group.

Table 4—*Results of soil nutrient and foliar analyses of planted Douglas-fir seedlings after 3 growing seasons on an eroded granitic soil near Sawyer's Bar in northern California*

Soil and foliar analyses		Unfertilized	Fertilized
		Mean ± S.D.	
Soil analysis:			
N (total)	(pct)	[1] 0.026 ± 0.007	0.026 ± 0.007
N (available)	(ppm)	2.8 ± 1.04	2.7 ± 1.35
P (available)	(ppm)	23.58 ± 8.097	23.85 ± 7.553
K (exchangeable)	(Meq)	0.17 ± 0.043	0.18 ± 0.079
Na (exchangeable)	(Meq)	0.21 ± 0.042	0.19 ± 0.031
Ca (exchangeable)	(Meq)	4.48 ± 1.086	4.38 ± 1.004
Mg (exchangeable)	(Meq)	1.41 ± 0.489	1.31 ± 0.446
Cat. exch. cap.	(Meq)	15.4 ± 4.02	14.1 ± 1.20
pH[2]		5.0 ± 0.15	5.1 ± 0.17
Org. matter	(pct)	0.59 ± 0.218	0.72 ± 0.297
Foliar analysis:			
N	(pct)	[3] 1.05 ± 0.171	1.01 ± 0.164
P	(pct)	0.38 ± 0.040	0.37 ± 0.037
K	(pct)	0.87 ± 0.088	0.83 ± 0.105
Ca	(pct)	0.30 ± 0.042	0.28 ± 0.040
Mg	(pct)	0.18 ± 0.016	0.19 ± 0.014
Cu	(ppm)	7.4 ± 1.22	7.4 ± 1.25
Zn	(ppm)	20.9 ± 4.29	20.7 ± 4.86
Mn	(ppm)	176 ± 90.9	182 ± 61.4
Fe	(ppm)	205 ± 76.2	186 ± 43.9

[1] Each mean is based on 12 composite samples from the 15- to 25-cm depth, except cation exchange capacity, which is based on 4.
[2] Calcium chloride method.
[3] Each mean is based on 18 composite samples.

Nutrient Analysis

Differences between treatment means (fertilized as against unfertilized) for each of the elements analyzed were small and are not statistically significant ("t" test at the 5 percent level) *(table 4)*. Three years after fertilization, the added nutrients were not detectable, either in the soil or in the plant.

DISCUSSION

Considering the adversity of the planting site (a coarse-textured, highly unstable granitic soil on a steep slope), the 3-year survival percentages for all treatments are surprisingly high. Survival is attributed to the use of good planting stock from an appropriate seed source, lifted at the proper time, properly stored, and carefully planted. In addition, most plots have a northeasterly aspect, which is generally favorable in terms of moisture availability. Also, the trees did not have to contend with competing vegetation.

Although the aspect is favorable, drought nevertheless is considered to be the most likely cause of first-season mortality. Precipitation during the 5 months from May 1 through September 30, 1975, was only 33 percent of the normal 4.39 inches (112 mm). Furthermore, the effect of drought on an individual seedling is not only a function of precipitation, soil moisture, air temperature, and humidity; it also depends on the root development and morphology of the seedlings, on the balance between roots and shoots, on whether a good planting hole could be dug, and whether or not the root system was injured in the planting operation. If any of these variables are unfavorable, the roots of the seedling may not absorb moisture fast enough to replace moisture [illegible] and the seedling wil

Several of the pla mostly large, coars paratively few fine other instances, a g was difficult to pr nearness to the surf parent rock that only slightly.

None of the tre excavated for post tion because of th that would result f tion. One facet of observe soil move planted trees as a forces. Because the trees were planted only 3 feet (0.9 m) apart, seedling excavation would have had considerable effect on soil stability around neighboring trees.

The only two trees recorded as missing during the annual survival counts could have been completely buried by soil dep however, this is process, and e had not

compared with only 1.05 percent for the unfertilized seedlings in this study. Foliar phosphorus, potassium, and calcium levels in this study were similar to those reported by Krueger, but manganese concentrations were much lower (176 as against 428 ppm), and iron concentrations much higher (205 as against 82 ppm).

In a series of laboratory experiments designed to determine the adequacy of various nutrients for growth of Douglas-fir and Sitka spruce (*Picea sitchensis* [Bong.] Carr.) seedlings, van den Driessche[23] concluded that an adequate nitrogen supply for Douglas-fir was associated with a needle analysis of 1.8 to 2.2 percent. These levels are comparable to the values obtained by Krueger and, therefore, are also about twice as high as the levels for foliar nitrogen found in this study.

Of probably greater importance, however, are the foliar nutrient concentrations that have been found to represent critical or deficient levels. Powers[24] reports such levels for three types of vegetation—conifers, hardwoods, and field crops. Comparing my values with those he reports for conifers, only foliar nitrogen was at a deficient level. Powers shows an adequate range for this element to be from 1.3 to 3.0 percent of dry weight; a level as low as 1.1 percent is considered deficient.

Critical levels have also been established for nutrient concentrations in the soil. Powers[24] reports that 25 ppm of bicarbonate-soluble phosphorus represents a critical level of this element, although he subsequently modified this to 17 ppm.[25] He also indicates that a value of less than 12 ppm for available soil nitrogen is considered deficient, except for granitic soils that invariably test low, even though they may be quite productive.

Although a deficiency of nitrogen may be one variable accounting for the poor height growth of the trees in this study, lack of sulfur may be another. I did not test for this element, but studies in Washington[26] have shown that trees with low foliar sulfate sulfur had low response to nitrogen fertilizer. The basis for this assessment is the known biochemical relationship between nitrogen and sulfur in protein, and the necessity for adequate foliar sulfur concentrations for nitrogen to be used by the plant.

Because the large stock was the same age (2-0) as the regular stock at the time of lifting, its larger size when lifted can be attributed either to genetic factors, or to more favorable microsite conditions in the nursery, or both. Without knowing the precise reason for its larger size at the start of the experiment, the reason for its superior growth after outplanting cannot be pinpointed.

The greater first-season vigor of the large stock, as compared with the regular, was probably because of their bushier, more massive root systems, as well as their more favorable top-root ratios. Their roots were apparently better able to supply the moisture required by the growing crown during the critical first season. By the end of the second year, however, with an intervening rainy season and cooler weather, many of the trees classified as weak after one growing season had had a chance to adjust to their field environment and had improved in vigor.

The fertilizer tablets probably had their peak effect during the second growing season. During that year only, the number of fertilized trees still classed as weak was significantly fewer than the number of unfertilized trees in this category. This conforms to expectations, since the slow-release tablets probably did not dissolve significantly until the first rainy season after planting.

All or nearly all trees in the study experienced soil displacement, especially deposition, to some degree. However, I recorded this phenomenon only when it was obvious. A seedling with a buildup of soil of about one-half inch (1.27 cm) or less around the base of the stem was not classed as experiencing deposition.

None of the seedlings in the study was planted in an existing gully, because I considered this to be too severe a microsite for this first test. The encouraging results to date, however, suggest that future studies should include planting in the bottoms of gullies, as well as on south or west aspects where moisture stress would be greater.

CONCLUSIONS

The results of this study, when combined with those from earlier ones, provide the land manager with information about the merits of certain techniques for establishing conifer seedlings on unstable granitic soils.

In this study, neither the use of large stock nor of supplemental fertilizer significantly improved the survival of 2-0 Douglas-fir trees. Survival of 78 percent or better for all treatments is attributed to the use of good stock from a suitable seed source, carefully lifted, stored, handled, and planted. Observance of these cardinal regeneration guidelines, therefore, may have already achieved the major gain in survival that can reasonably be expected on such an adverse site.

Height growth, however, was significantly improved by planting large trees—trees that were characterized not so much by superior initial height as by a relatively large stem diameter, dense, full crown, and well-developed, bushy root system. A good balance between top and root development (T-R ratio averaging about 1.30) also characterized these seedlings. Because the large stock in this study was obtained by grading the plantable nursery stock into two size classes at the time of lifting and packing, little added cost was incurred. It appears worthwhile for the regeneration forester to select large seedlings for revegetating such unstable granitic soils, and to plant the smaller trees on less severe sites.

Fertilization improved 3-year height growth, though to a lesser extent than did the use of large stock. The height growth increase from using large stock, as opposed to regular, ranged from 82 to 93 percent. For fertilized as against unfertilized, however, the increase in height growth ranged from 25 to 32 percent. Fertilization involves added expense because of the cost of the tablets and the extra labor required for their proper placement. On erodible sites, however, where rapid, early height growth may be an asset of considerable value to a land manager, he may consider that the combined benefits of using large stock and fertilization are a sound investment.

NOTES

[1] Megahan, Walter F. 1974. *Deep-rooted plants for erosion control on granitic road fills in the Idaho Batholith.* USDA Forest Serv. Res. Paper INT-161, 18 p. Intermountain Forest and Range Exp. Stn., Ogden, Utah.

[2] Roy, Douglass F. 1961. *Seed spotting with endrin-treated Douglas-fir seed in northwestern California.* USDA Forest Serv. Tech. Paper 61, 12 p. Pacific Southwest Forest and Range Exp. Stn., Berkeley, Calif.

[3] Bernsten, Carl M. 1958. *A test planting of 2-0 and 3-0 Douglas-fir trees on a steep south slope.* USDA Forest Serv. Res. Note 165, 4 p. Pacific Northwest Forest and Range Exp. Stn., Portland, Oreg.

[4] Seyfert, Carl K. 1974. *Geology of the Sawyer's Bar quadrangle.* In *Geologic guide to the southern Klamath Mountains,* D. McGeary, ed., p. 69-81. Dep. Geol., Calif. State Univ., Sacramento, Calif.

[5] Dougherty, Raymond. *Task Force report of the Little North Fork drainage storm damage and environmental problems.* Unpublished 1972 report on file at Pacific Southwest Region, Forest Service, U.S. Dep. Agric., San Francisco, Calif.

[6] Abraham, Dan. *Little North Fork Study Area Report.* Unpublished 1973 report on file at Salmon River District, Klamath National Forest, Sawyer's Bar, Calif.

[7] Pillsbury, Norman H. 1976. *A system for landslide evaluation on igneous terrane.* Ph.D. dissertation. On file at Dep. Earth Resources, Colorado State Univ., Fort Collins, Colo.

[8] Agriform Forest Starter Tablets (18-8-3), manufactured by Sierra Chemical Co., Newark, Calif.

[9] Trade names and commercial enterprises or products are mentioned solely for information. No endorsement by the U.S. Department of Agriculture is implied.

[10] Lavender, Denis P. 1970. *Foliar analysis and how it is used—a review.* Oregon State Univ. Forest Res. Lab. Res. Note 52, 8 p. Oregon State Univ., Corvallis, Oreg.

[11] Mitchell, H. L. 1972. *Microdetermination of nitrogen in plant tissue.* J. Assoc. Official Analytical Chemists 55(1):1-4.

[12] Johnson, C. M., and A. Ulrich. 1959. *Analytical methods for use in plant analysis.* In *Report of the Calif. Agric. Exp. Stn. Bull.* 766, p. 28-35 (March 1959).

[13] Murphy, J., and J. P. Riley. 1962. *A modified single solution method for the determination of phosphate in natural waters.* Anal. Chim. Acta 27:31-36.

[14] Perkin-Elmer. 1976. *Analytical methods for atomic absorption spectrophotometry.* Sept. 1976 supplement to 1973 ed., Perkin-Elmer Co., Norwalk, Conn. (Loose-leaf; no consecutive pagination.)

[15] Catlado, D. A., L. E. Shrader, and V. L. Youngs. 1974. *Analysis by digestion and colorimetric assay of total nitrogen in plant tissues high in nitrate.* Crop Sci. 14:854-856.

[16] Waring, S. A., and J. M Bremner. 1964. *Ammonium production in soil under waterlogged conditons as an index of nitrogen availability.* Nature 201:951-952.

[17] Bray, R. H., and L. T. Kurtz. 1945. *Determination of total, organic, and available forms of phosphorus in soil.* Soil Sci. 59:39-45.

[18] Chapman, H. D. 1965. *Cation-exchange capacity.* In *Methods of soil analysis,* Part 2, p. 891-900. C. A. Black, D. D. Evans, J. L. White, L. E. Ensminger, and F. E. Clark, eds. Amer. Soc. Agron., Madison, Wis.

[19] Allison, L. E. 1965. *Organic carbon.* In *Methods of soil analysis,* Part 2, p. 1367-1378. C. A. Black, D. D. Evans, J. L. White, L. E. Ensminger, and F. E. Clark, eds. Amer. Soc. Agron., Madison, Wis.

[20] Peech, Michael. 1965. *Hydrogen-ion activity.* In *Methods of soil analysis,* Part 2, p. 914-925. C. A. Black, D. D. Evans, J. L. White, L. E. Ensminger, and F. E. Clark, eds. Amer. Soc. Agron., Madison, Wis.

[21] Kendall, Maurice G., and Alan Stuart. 1967. *The advanced theory of statistics.* Vol. 2, 2d ed. Inference and relationship, p. 553-556. Hafner Publ. Co., New York.

[22] Krueger, Kenneth W. 1967. *Foliar mineral content of forest- and nursery-grown Douglas-fir seedlings.* USDA Forest Serv. Res. Paper PNW-45, 12 p. Pacific Northwest Forest and Range Exp. Stn., Portland, Oreg.

[23] van den Driessche, R. 1969. *Tissue nutrient concentrations of Douglas-fir and Sitka spruce.* British Columbia Forest Serv. Res. Note 47, 42 p., Victoria, B.C.; Canada.

[24] Powers, Robert F. 1976. *Principles and concepts of forest soil fertility.* In *Proc. First earth sciences symp., Calif. Region.,* p. 1-33. Forest Serv., U.S. Dep. Agric., San Francisco, Calif.

[25] Personal communication from Robert F. Powers, July 1979.

[26] Turner, John, Marcia J. Lambert, and Stanley P. Gessel. 1977. *Use of foliage sulphate concentrations to predict response to urea application by Douglas-fir.* Can. J. For. Res. 7:476-480.

The Author

R. O. STROTHMANN is doing research on intensive timber culture of northwestern California conifers, with headquarters in Arcata, California. He earned bachelor's (1950), master's (1951), and Ph.D. (1964) degrees in forestry at the University of Michigan, and has been on the Station's staff since 1964.